EXECUTIVE SUMMARY

Field Validation of Visual Cleaning Performance Indicator (VCPI) Technology

ESTCP Project WP-0410

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Background

This report summary serves to provide an abbreviated background on the above referenced Environmental Security Technology Certification Program (ESTCP) project, as well as document several issues that were encountered throughout the execution and completion of the project. The contents of this summary were drafted by the Project Manager (PM) at Battelle, and are not intended to reflect the engineering opinions and judgments of the DoD stakeholders that participated in the project. It is the PM's intent to provide a summary of the successes and shortcomings of the project, as well as identify what would be necessary to implement the VCPI technology into the maintenance facilities at both Hill Air Force Base (Hill AFB) and Mayport Naval Station (MNS).

The Strategic Environmental Research and Development Program (SERDP) office funded a project in FY2000 to demonstrate the feasibility of using environmentally compliant and food safe dyes to selectively label specific contaminants routinely found on the large area surfaces of Air Force aircraft and Navy ships. The cleaning and re-cleaning of these surfaces is critical to the quality of the corrosion protection system(s) or paint system stack-up applied to these structures to maintain their integrity and end-user availability. The Air Force (i.e., Air Force Research Laboratory (AFRL)) and Navy (i.e., Naval Surface Warfare Center – Carderock Division (NSWC-CCD)) stakeholders that participated in the SERDP project agreed to investigate the VCPI technology as a means of replacing the traditional "water break" cleaning verification test with a more user-friendly, real-time method that is more accurate and potentially represents cleaner surfaces, lower labor costs, and a reduced usage of cleaning materials.

The SERDP project (ref. PP-1117), which was completed in May 2002, had several accomplishments related to the VCPI technology, which included:

- a selection of several Commercially-Off-The-Shelf (COTS) dyes and carrier agents that were environmentally safe for depot use, and capable of "selectively" labeling several different surface contaminants that were identified by the Air Force and Navy stakeholders. These contaminants included: hydrophobic soils (i.e., greases and oils), soluble salts, aluminum-based corrosion products, and plastic media blasting (PMB) residues. The stakeholders were able to identify and qualify the "affected" weapon systems and level of contamination confined to the large area surfaces of the representative structures or platforms being identified for further investigation
- an identification of water-soluble dyes that have a chemical affinity or attraction to specified contaminants, and subsequent laboratory validation of VCPI application (density and distribution), labeling efficiency (concentration and dwell time), and detection (visual and analytically) of contaminants common to the surfaces of various types of metallic and non-metallic test panels
- a successful laboratory demonstration completed on representative test panels by the Air Force, Navy and Battelle

- recommendations to proceed to a “full-scale” demonstration/validation of the VCPI technology on military assets

Supporting projects completed by Boeing-Commercial and the Environmental Management Office at Hill AFB during the FY 2003 to 2005 time period also supported the use of the VCPI technology for specific cleaning verification applications. Specifically, Boeing-Commercial has adopted the use of an optimized derivative of the VCPI technology to identify locations and quantities of silicone-based residues on metallic and composite aircraft structures prior to cleaning and painting. Hill AFB engineers responsible for the day-to-day processing of aircraft landing gear components in the Plating Shop located in Building 507 agreed to evaluate the VCPI technology on off-aircraft component parts that are routinely “dip” cleaned in several large volume plating tanks as part of the pre-paint “wash-etch-alodine” processing operations. The results obtained from this latter study, as well as the Boeing study confirmed that the pre-selected VCPI dyes identified during the SERDP project were able to successfully label varying levels or concentrations of surface contaminants. Collectively, these results and the results obtained from the laboratory testing completed during the SERDP funded project led the DoD stakeholders and Battelle to recommend that an ESTCP project be funded to validate the technology in a production environment on full-scale aircraft and ship structures. These recommendations led to the funding of the above referenced ESTCP project. Several results and “lessons learned” obtained throughout the completion of this project are provided in the following summary.

Project Successes

The subject ESTCP funded project was considered a partial success from the standpoint that the respective Dem/Val tests validated the results obtained during the above reference laboratory- and field-based studies. Specifically, the selected VCPI dye solutions were (1) easily prepared in the concentrations required to quickly label the varying degrees of contamination on large area surfaces, and (2) able to be efficiently spray dispersed onto the targeted structures identified by the Air Force and Navy representatives. The VCPI dye solutions visually labeled hydrophobic soils (i.e., greases and oils) on the underside surfaces of a single A-10 aircraft at Hill AFB, as well as soluble salt residues on the painted forward hull surfaces of the USS Halyburton at MNS. The resonance time for the dyes on the surfaces was minimal, the visual detection limits were optimal for the conditions within the respective Dem/Val environments, and the dye/contaminant removal rates were acceptable for the surfaces being investigated.

Recommendations made by the DoD stakeholders at the conclusion of the SERDP project included using the VCPI technology to verify presence and/or absence of PMB residues along the outer mold line (OML) surfaces of the F-16 aircraft, as well as document the presence and adverse effects of soluble salts during the re-painting of Navy ship hulls. Both of these contaminants were known to contribute to localized paint adhesion failures; hence, the Dem/Val platforms were very focused to specific maintenance operations/problems. However, the extent of the problems associated with the PMB residues was significantly reduced by the time the ESTCP project was funded. The media vendors reformulated the Type V media such that the post-coating removal residue

problems were eliminated. As a result, an alternative approach for contaminant detection and/or cleanliness verification on the A-10 platform was recommended by the Air Force stakeholders at Hill AFB. Results collected during the Dem/Val test completed at this demonstration site confirmed that the VCPI technology is not an appropriate cleaning verification tool for the T.O 1-1-8 approved Prekote™ surface treatment processes used to prepare the OML surfaces of aircraft structures maintained at this maintenance facility. Specifically, the technology was able to selectively label surface contamination on the aircraft structures; however, the inclusion of the technology into existing pre-paint cleaning operations documented in the respective weapon system specific Process Orders (POs) involved extra processing steps (i.e., application, inspection, and removal) which require additional time and manpower expenditures. As a result, this particular site demonstration supported the following conclusions that were captured during post-Dem/Val discussions with the management and production staff:

- the VCPI technology was able to visually document the advantages associated with a power scrub, when compared to a manual pole scrub
- the extra processing steps required to spray apply and then remove the VCPI dyes from “target” and adjacent aircraft structures are not acceptable when considering the current 3-stage Prekote processing operations
- additional masking of critical painted structures would be required prior to applying the VCPI dyes to the surfaces of target structures – again, unacceptable when considering current Prekote pretreatment operations
- requirement for dye containment to avoid staining of operators’ Personal Protective Equipment (PPE) and surrounding infrastructure
- the VCPI technology does have a potential application at Hill AFB, in that it could be used as an inexpensive, “real-time” quality control tool for validating the differences in cleaning efficiency for the personnel assigned to the 3 shifts responsible for processing the A-10, F-16, and C-130 aircraft
- the VCPI technology may have other unique applications similar to the Plating Shop efforts described in the previous text.

The Navy Dem/Val test successfully confirmed that the pre-selected VCPI dye solution was capable of labeling varying concentrations of soluble salt residues on the painted hull surfaces of the weapon system platform (i.e., USS Halyburton). Once labeled, these contaminants were visually apparent and able to be efficiently removed with a medium pressure water rinse. Obviously, the test verified the benefits associated with “knowing where the contaminants are and realizing that they are effectively removed with concentrated water rinsing”. As with the Air Force A-10 cleaning demonstration; however, the intended use on ship hull surfaces requires several additional non-routine processing steps. Specifically, the spray application, visual inspection and additional cleaning (i.e., agitation and water rinsing) associated with the removal of the contaminant/VCPI dye requires time and manpower suggesting that the “real time” benefits related to improved cleaning are negligible. The strength of the anticipated benefits would have been realized if the improvement in paint adhesion and corrosion protection to the underlying hull structures could have been demonstrated within the time allotted for this project. The lack of maintenance data (i.e., paint peeling, removal,

surface preparation and treatment, and repainting) for this test platform also lessened the environmental and economic benefits associated with using the VCPI technology.

Project Failures

The technical approach selected for the Dem/Val tests conducted at both Hill AFB and the Mayport Naval Station failed to recognize the lack of maintenance data necessary to support the alternative cleaning verification technique investigated in the ESTCP project. The Air Force and Navy stakeholders indicated at the initiation of the project that there were random paint adhesion failures on selected areas and/or structures of both aircraft and ships. In most instances, the stakeholders and weapon system engineers verbally stated that the lack of paint adhesion was primarily due to an improper pre-cleaning of the metallic and/or composite structures prior to applying the primer and topcoat stack-ups. The approved "water-break" test is considered by many of the reporting maintenance personnel to be subjective and not the most accurate or reliable method of determining the pre-paint cleanliness of a structure or component part. Unfortunately, there is little documented data supporting the location, source, and frequency of paint adhesion failures on both the A-10 and Navy frigate platforms. For this reason, this project was not able to accurately compare the cost/performance advantages and disadvantages of the VCPI technology to existing practices as well as capture any post-processing benefits associated with the VCPI technology (i.e., improved paint adhesion and reduced substrate corrosion damage).

Additional process-related failures encountered during the Dem/Val tests that potentially may limit the acceptance of the VCPI technology in a large area surface cleaning operation include the dye staining of support equipment, adjacent structures, PPE and surrounding infrastructure. The time and personnel required to protectively mask and/or clean-up the surfaces of these non-targeted structures offsets any savings associated with the time, manpower, and materials savings proposed from the use of the VCPI technology. Finally, the costs associated with containing the VCPI dye solutions used for pier-side Navy ship applications also represent a negative factor (economic and environmental) in the DoD acceptance of the VCPI technology.

Recommendations for Technology Implementation at Hill AFB and Mayport Naval Station

Battelle engineers have received verbal statements from the Air Force stakeholders that the VCPI technology has limited use as a quality control tool for verifying surface cleanliness. The application, inspection, and removal process would be confined to specific aircraft structures. Targeted weapon system platforms include the A-10, F-16, and C-130 aircraft. In addition, the technology can be successfully applied in the current dip-tank component parts cleaning operations conducted at both Hill AFB and MSN. For this application, a separate water rinse dip tank would be modified with specific VCPI dye solutions. Dipping the "as-cleaned" parts into this tank prior to a final wash and/or cold water rinse would verify that all surface contaminants are completely removed from difficult-to-access areas on the parts. Obviously, the tank could contain several different VCPI dyes that are specific for possible depaint, dye penetrant inspection, solvent, and hydrocarbon-based contaminants that may be on the surfaces of the component parts.

Finally, the VCPI technology would have greater user acceptance if the dye solution could be added to an existing cleaning operation. The end-user needs to be able to use the cleaning verification tool without creating an additional processing step or requiring additional scheduling and manpower commitments. The most logical "point-of-application" is the final water rinsing of the component parts and structures or large area surfaces of DoD equipment. For this scenario, the VCPI dye must not compromise appearance, primer adhesion and the corrosion resistance of the underlying substrate materials.